UNITED STATES PATENT APPLICATION

FOR

SURFACE MAINTENANCE TOOL POWER CONTROL SYSTEM

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CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This non-provisional United States (U.S.) Patent Application claims the benefit of Provisional U.S. Patent Application No. 60/461,948, filed April 10, 2003 by inventor Jolyon Crane et al., and titled "Surface Maintenance Tool Power Control System."

FIELD OF THE INVENTION

[0002] Various embodiments of the invention pertain to floor maintenance tools such as scrubbing machines. More particularly, at least one embodiment of the invention relates to a feedback control system for operating a brush motor according to the power exerted by the motor.

DESCRIPTION OF RELATED ART

[0003] Surface maintenance machines have been used, for instance, to clean and/or scrub floors. Typically, floor maintenance machines, such as floor scrubbers, are mobile devices which roll on top of a surface as said surface is cleaned, scrubbed, or otherwise maintained. Because of their mobile nature, such floor maintenance machines are typically battery powered. As the floor maintenance machine operates, it drains the battery power while diminishing battery voltage. A system which sets the operating mode of a machine by merely measuring the current to the tool/brush motor would prove inaccurate as the voltage drops. Additionally, a system which does not consider the torque exerted by the tool/brush motor will not compensate for differing surfaces and cleaning requirements.

[0004] U.S. Patent No. 4,674,142 discloses a floor-cleaning tool with an electric motor for controlling the position of the brush head relative to the floor and a pressure-sensing device mounted on a lever arm carrying the brush head. Based on the sensed pressure by the pressure-sensing device, the control motor adjusts the position of the brush head relative to the floor to maintain a desired brush pressure.

[0005] U.S. Patent No. 4,757,566 discloses an automatic torque compensator for a surface maintenance machine such as a sweeper or scrubber. The torque compensator automatically varies the pressure on the scrubber to maintain a desired torque in the scrubber even when the surface may vary in its resistance to the scrubber. The torque compensator senses the load current on the electric motor driving the scrubber and varies the pressure on the scrubber to maintain a desired torque.

[0006] U.S. Patent No. 6,163,915 discloses a battery-operated floor cleaning machine in which the load current of a brush drive motor is representative of the operating pressure of the pad, as the operating pressure increases or decreases, the current of the drive motor increases or decreases accordingly. A controller compares the signal representative of the actual operating pressure with a signal representative of a desired brush pressure. The difference between these signals is used to control an actuator to adjust the brush pressure to achieve the desired brush pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure 1 is a floor-maintenance machine in which a power control system may be implemented according to one embodiment of the invention.

[0008] Figure 2 is a block diagram illustrating a power control system for a floor-maintenance tool or brush motor according to one embodiment of the invention.

[0009] Figures 3A and 3B are a block diagram illustrating a power control system according to one embodiment of the invention.

[0010] Figures 4-7 illustrate various power selection methods that may be used to select a desired brush power.

[0011] Figure 8 illustrates a power control method for a floor-maintenance machine according to one embodiment of the invention.

SUMMARY OF THE INVENTION

[0012] One embodiment of the invention relates to a power control system for a floor-maintenance tool. The power control system measures the overall power exerted by the tool motor, including the current through the tool motor and the voltage level of the power source to the tool motor. The power control system then determines the difference between the measured motor power and a selected desired operating power, and, if this difference is greater than a threshold error, automatically adjusts the force exerted upon the tool motor to either increase or decrease the tool motor power to reach the desired operating power.

[0013] One embodiment of the invention may be found in a floor-maintenance tool having a control system that maintains the tool operating at a desired power level. A tool motor is electrically coupled to a power source and rotates a floor brush. A power selection switch is used to select a desired operating power for the tool motor. An actuator is configured to exert an amount of force upon the tool motor. The control system is configured to measure the overall power exerted by the tool motor, including current and power source voltage, determine the difference between the measured motor power and a selected desired operating power. If the difference between the measured motor power and selected desired operating power is greater than an acceptable threshold amount, the control system automatically adjusts the force exerted upon the tool motor to either increase or decrease the tool motor power to reach the desired operating power.

DETAILED DESCRIPTION

[0014] Methods and systems that implement the embodiments of the various features of the invention will now be described with reference to the drawings. The drawings and the associated descriptions are provided to illustrate embodiments of the invention and not to limit the scope of the invention. Reference in the specification to "one embodiment" or "an embodiment" is intended to indicate that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least an embodiment of the invention. The appearances of the phrase "in one embodiment" or "an embodiment" in various places in the specification are not necessarily all referring to the same embodiment. Throughout the drawings, reference numbers are re-used to indicate correspondence between referenced elements. In addition, the first digit of each reference number indicates the figure in which the element first appears.

[0015] In the following description, certain terminology is used to describe certain features of one or more embodiments of the invention.

[0016] Various aspects of the invention provide a method of controlling a floor maintenance tool so as to maintain the power exerted by the tool constant for a particular desired setting.

[0017] One embodiment of the invention provides a feedback control system that may be part of a surface maintenance machine and can automatically measure brush power and adjust the pressure on a brush to maintain the power substantially at a desired power setting. One aspect of the invention maintains a rotary tool at a user-selected power level even as the voltage level of the power source (e.g., batteries) diminishes. This is done for as long as the power source can provide a minimum level of voltage and/or a maximum amount of current.

[0018] It should be noted that, typically, the power exerted by a motor driving a rotary tool is not the same as the power going into the motor. The motor's efficiency curve determines how

much of the power going into the motor is actually exerted by rotary tool. However, in one embodiment of the invention, measuring, regulating and/or adjusting the power going into the motor serves to also regulate the power exerted by the rotary tool (e.g., brush). Additionally, since a motor's efficiency curve is typically known, one embodiment of the invention determines the power into the motor and uses the motor's efficiency factor or curve to determine the power transferred by the motor to the rotary tool (e.g., brush). Thus, various embodiments of the invention may be implemented by determining the power going into the drive motor and/or the power exerted by the motor to drive the rotary tool (e.g., brush).

[0019] Figure 1 is a floor-maintenance machine 100 in which a power control system may be implemented according to one embodiment of the invention. The floor-maintenance machine 100 may be a mobile machine including one or more wheels 102 to permit the floor-maintenance machine 100 to move over a surface 104 to be cleaned. The floor-maintenance machine 100 may also include a propelling system 110 (e.g., motor, drive mechanism, etc.) to rotate the wheels 102 and move the floor-maintenance machine 100 and a steering system to steer the machine 100 in a desired direction. A power source 106, such as one or more batteries or fuel cells, may provide power to propel the floor-maintenance machine 100, one or more rotary tools or brushes 108, and/or other devices, including the power control system 112. The power control system 112 may include a plurality of sensors, to detect the operating condition of the power source 106 (e.g., current and/or voltage) and the power exerted by the rotary tool or brush 108, and one or more actuators 114 to increase or decrease the downward force exerted on the rotary tool or brush 108. The rotary tool or brush 108 may be rotated by one or more motors 116 which rotation speed is controlled by the power controller system 112 (e.g., processor, controller, etc.). A power selector 118 permits an operator to select the desired brush power.

[0020] In one implementation of the invention, the floor-maintenance machine 100 may also include a squeegee, vacuum and/or blower arrangement mounted on the floor-maintenance machine 100 to clean the surface 104. In various embodiments of the invention, the floor-maintenance machine 100 may be a ride-on machine or a walk-behind machine.

[0021] Figure 2 is a block diagram illustrating a power control system 200 for a floor-maintenance tool or brush motor according to one embodiment of the invention. A brush power selector 202 serves to select a desired power value 212 for a brush motor 204. The power exerted by the brush motor 204 may be determined by multiplying 205 the current 220 passing through the brush motor 204 and the voltage level 218 of the power supply 206 (e.g., battery). A 'power error' 208 is calculated by the difference between the measured power value 210 and a desired power value 212. This power error 208 is compared 213 to a maximum or threshold permitted error 214. If the power error 208 is greater than the maximum permitted error 214, then magnitude of the power error 208 is used to adjust 217 the actuator 216 to reduce the power error 208. Otherwise, the actuator 216 is not adjusted 215.

[0022] The amount of power exerted by the brush motor 204 may be modified by raising or lowering the actuator motor 216 to either increase or decrease the force exerted on the brush motor 204 against the surface to be cleaned or brushed. Increasing or decreasing the force exerted on the brush motor 204 causes an increase or decrease, respectively, of the power drawn by the brush motor 204.

[0023] According to one implementation of the invention, the measured power value 210 corresponds to the actual power going into the brush motor 204. This measured power value 210 takes into account both the current drawn by the brush motor 204 as well as the voltage level of the power source 206. The voltage level 218 of the power source 206 may be determined by any

of several ways known to those skilled in the art (e.g., multimeter, etc.). The similarly, the current 220 through the brush motor 206 may be determined in a variety of ways known to those skilled in the art. The measured power source voltage 218 and/or the measured current 220 may be converted into digital values by for purposes of calculating power. For instance, and analog-to-digital converter 222 may serve to convert a current signal to a digital value. The current value may also be scaled 224 to take into account calibration factors 226, etc.

[0024] As previously noted, some embodiments of the power control system may compare the power going into the brush motor 204 to a desired power level. However, other embodiments of the invention may compare the brush power, determined by using the power going into the brush motor and the motor's efficiency rating, factor, or curve, to the desired power level. Ultimately, either the power going to the drive motor or the power exerted by the brush may be used to achieve the same result of maintaining a desired power level that takes into account both the voltage level of the power source and the current to the drive motor.

[0025] In one implementation of the invention, one or more of the operations for maintaining the motor/brush power at a desired power setting may be performed by a processing unit 226 configured to receive the necessary inputs and perform the above described operations.

[0026] Figures 3A and 3B are block diagrams illustrating a power control system 300 according to one embodiment of the invention. The power control system 300 may be part of a surface maintenance machine that automatically measures motor/brush power and adjust the pressure on a brush 302 to maintain the actual motor/brush power substantially at a desired power setting 304.

[0027] In one embodiment of the invention, a field effect transistor (FET) 306 may be employed to turn the brush motor 308 On and Off. A combination of resistors may be employed

to provide the voltage drop across the FET 306 to an analog-to-digital converter 310. The analog-to-digital converter 310 provides a digital voltage value 312, corresponding to the measured voltage drop across the FET 306, to a microprocessor. The digital voltage value 312 may then be scaled 313 using a calibration factor 311 (e.g., FET resistance) to determine a measured motor current 315. Similarly, the voltage level of the power source 314 (e.g., batteries) to the brush motor 308 may be measured and converted to a digital value 316. The measured power source voltage value 316 is then multiplied 317 with the measured motor current 315 to determine a measured overall power 318 for the brush motor 308.

[0028] In one implementation of the invention, the measured brush motor power 318 may be converted to a percentage brush motor power value 322 by dividing 319 the measured motor power 318 by a calibration factor 323.

[0029] A power error value 320 may be calculated by subtracting 321 the percentage motor power value 322 from the desired power value 304. Note that, when the brush motor power value is represented as a percentage 322, the desired power value 304 is also a percentage of the desired power value. This power error value 320 is then compared to a permitted power error value 324. If the power error value 320 is greater than a permitted power error value 325, then a modified actuator motor speed 329 is calculated 333 from the difference between the power error value 320 and the permitted power error value 325. A brush pressure factor 327 may be used to calculate 337 an adjusted actuator speed 329. On the other hand, if the power error value 320 is less than the permitted power error value 325, then the actuator motor speed 326 is set to zero. In one implementation of the invention, a minimum actuator speed 328 may be added 341 to the adjusted actuator speed 329. Another aspect of the invention provides for limiting the brush actuator speed 329 to within an allowable range of actuator speeds 330.

[0030] The adjusted actuator speed 329 is used to activate the brush position actuator 332 to either increase or decrease the force exerted on the brush 302 as necessary to reduce the power error value 320. The actuator 332 may raise or lower the brush 302 to provide the desired brush motor power 304. An increase of force on the brush 302 causes an increase in the power drawn by the brush motor 308. Conversely, reducing the force on the brush 302 causes a decrease in the power exerted by the brush motor 308. By calculating the overall brush motor power 318 (i.e., measured motor load current 315 X power source voltage 316), the control system 300 is able to maintain the desired brush motor power 304 even as the voltage level of the power source 314 (e.g., batteries) diminishes. Additionally, such control system 300 is also able to maintain the brush motor 308 operating at a desired power level 304 even when the surface being brushed varies in smoothness (e.g., goes from rough to smooth).

[0031] According to one implementation of the invention, the brush actuator speed 329 may be further processed to activate the brush position actuator 332. For instance, a speed multiplier 334 may be used to scale or calibrate the brush actuator speed 329 to the specifications of the brush actuator 332 and provide a first modified brush actuator speed 331. Additionally, a Hop-On Function 335 serves to guarantee a minimum actuating speed for moving the actuator motor 332. This may be desirable since actuators sometimes do not operate well below a minimum threshold speed. Thus, prior to activating the actuator 332, the system checks to make sure that the speed which will be selected for the actuator is above a minimum actuator threshold. For example, if the first modified brush actuator speed 331 is greater than zero (0) but less than a first threshold speed (e.g., 12.5%) then the output actuator speed 336 is the first threshold speed, if the brush actuator speed 329 is less than zero (0) and greater than a second threshold speed

(e.g., -12.5%) then the output actuator speed 336 is the second threshold speed, otherwise, the output actuator speed 331 is used.

[0032] In one embodiment of the invention, a pulse width modulation (PWM) generator 338 and other circuitry 339 may be used to convert the output actuator speed 336 to actual electrical signals to the actuator 332.

[0033] Figures 4-7 illustrate various power selection methods that may be used to select a desired motor/brush power. Figure 4 illustrates a 3-Position Toggle Switch selector 402, Figure 5 illustrates a Potentiometer selector 502, Figure 6 illustrates a Up/Down Push Button selector 602, and Figure 7 illustrates a Momentary Toggle Switch selector 702 that may be used to select the desired power 304 (Fig. 3). The selected desired power may be converted to a desired digital power value by an analog-to-digital converter 404. An index table 406 may be used to convert the desired digital power value to a corresponding index 408. A look-up table 410 may be used to convert the index to a corresponding power value 412 which can be used as the desired motor/brush power 414. Similarly, the potentiometer selector 502 of Figure 5 may be converted to a desired motor/brush power 514. When the Up/Down Push Button selector 602 or Momentary Toggle Switch selector 702 are used, the selected value may be converted to an digital value using an analog-to-digital converter 604, 704. A threshold detector 605, 705 may then be used to either count up/down 606 or set a power setting 706. A look-up table 608 may then be used to convert the selected value 606, 706 to a corresponding internal power value 612, 712 which can be used as the desired motor/brush power 614, 714 respectively.

[0034] Figure 8 illustrates a power control method for a floor-maintenance machine according to one embodiment of the invention. A power control system receives a first signal corresponding to the current utilized by the floor maintenance machine 802. The power control

system also receives a second signal corresponding to the voltage level of the power source for the floor maintenance machine 804. The first signal and second signal are then sampled to determine the actual power exerted by the floor maintenance machine 806 (e.g., power into the drive motor, or power exerted by the brush). The power control system then compares the actual drive motor/brush power to the selected power 808. The pressure exerted on the floor maintenance tool is adjusted (e.g., increased/decreased) to match the actual power to the selected power 810.

[0035] The method illustrated in Figure 8 may be stored in machine-readable medium. A machine-readable medium includes any mechanism that provides (i.e., stores and/or transmits) information in a form readable by a machine (e.g., a computer). For example, a machine-readable medium includes read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, and electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.).

[0036] While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other changes, combinations, omissions, modifications and substitutions, in addition to those set forth in the above paragraphs, are possible. Those skilled in the art will appreciate that various adaptations and modifications of the just described preferred embodiment can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.